

McCULLOUGH RESEARCH

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PRINCIPAL

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To: McCullough Research Clients

From: Robert McCullough

Subject: Update of CGS Nuclear Power Plant Operating Costs versus the Market Price of Carbon-Free Replacement Power and the Implications for Bonneville and Regional Utilities

This paper updates the latest numbers on the Columbia Generating Station nuclear power plant (CGS). It should be held to a market test as agreed to by BPA and Energy Northwest in 1999. Failure to meet that test should lead to its replacement by clean, renewable sources of electricity.

1) CGS Market Test

As outlined in previous McCullough Research reports since December 2013, The Columbia Generating Station provides the Bonneville Power Administration with the most expensive power in its generation portfolio. Since 2008, the plant has had operating and incremental costs far above market alternatives.

Recent management problems aside, the primary issue is simply the poor location of the plant, its scale of operations, and its age.^{1,2,3,4} The falling cost of electricity has plagued the plant for the last decade and does not look likely to abate in the foreseeable future.

¹ A variety of press reports describe three unplanned outages in the last two years and indicate that a group of whistleblowers have identified management and safety issues with the plant.

² The Hanford location places the plant at the center of the Mid-Columbia (Mid-C) market. It is also at the center of a vast expansion of renewable resources. The surplus in energy at this location can overwhelm transmission capacity to loads on the I5 corridor and force prices to levels below zero.

³ Many nuclear plants are “twins” which assures economies of scale and operation. The “triplets” of CGS were cancelled thirty years ago.

⁴ CGS was designed in 1970s. It is now in its thirty-fourth year of its original expected design life of forty years. While there is nothing impossible about operating an aging nuclear power station, ongoing capital costs and required upgrades make these plants uneconomic. The rash of recent nuclear plant closure announcements in Vermont, California, Pennsylvania, New Jersey, Massachusetts, and Nebraska reflect the cost of maintaining vintage plants in the face of more cost-effective alternatives.

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In 1999, the administrator of the Bonneville Power Administration – the federal agency that funds the project and sells its output through a “net billing” contract – and the Chief Executive Officer of Energy Northwest (then named the Washington Public Power Supply System (WPPSS)) agreed that the plant would be closed if it could not meet an annual four year “market test.”

The “market test” is quite simple: check whether the plant’s output was worth more than its operations over the last four years. This has not been true for CGS since 2008. Based on forward market bids and offers at the Chicago Mercantile Exchange, this situation is likely to still be true in 2022.⁵

In the 1990s, BPA had been wary of the CGS’ costs versus alternatives. In 1998, during the extensive regional review of costs and policies, the cost-review committee of the Comprehensive Review recommended that CGS be measured against market prices:

Washington Nuclear Plant 2: Combine aggressive cost management with a flexible response to market conditions and unforeseen costs. Manage annual operating costs to annual revenues achievable at market prices. Sell a portion of Bonneville's power, equal to the output of CGS, at a price that will recover the plant's operating costs. Test the plant's power prices against market prices every two years, and evaluate terminating the plant if projected operating costs exceed projected revenues. If revenues exceed costs, use a portion to build a decommissioning fund. Estimated annual savings: \$19 million.⁶

BPA accepted the recommendations.

The BPA Proposed Plan:

BPA agrees with the basic objective of the Cost Review recommendation, “to ensure that the operations of the plant not be insulated from the discipline of the marketplace” and to achieve the recommended increase in net operating revenues.

BPA intends to subject CGS operating costs to a market test biennially, testing whether market value of the CGS output recovers annual operating costs

⁵ The prices from the Chicago Mercantile Exchange are not forecasts. A forward market allows any market participant to place orders for future supplies at the posted prices. Colloquially, it is the equivalent of an energy “Costco,” where you can fix prices of future supplies by buying ahead of requirements.

⁶ Northwest Power and Conservation Council. *Issue brief no. 98-10. 1998 Briefing Book*. Nwcouncil.org. May 1998. Web. 15 Oct. 2013. <<http://www.nwcouncil.org/reports/1998/98-10>>.

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of the plant. BPA intends to solicit input on the precise nature of this market test in a public process this year.

Likewise, as recommended in the Review, BPA intends to re-evaluate plant termination if operating costs are projected to exceed revenues achievable at market prices by more than the termination costs.

With the cost and revenue projections assumed by the Cost Review, this would require about \$19 million of operating cost reductions and/or revenue increases. BPA will work with the Supply System to achieve as much of this enhancement of net revenues as possible through reductions in operating costs.

BPA intends to work with the Supply System to achieve additional operating cost efficiencies, avoid major capital additions, shorten outages, and, potentially, change from an annual to a biennial refueling cycle (would reduce from 5 to 2 the number of refuelings during next 5-year rate period).

Cost reductions assume, in part, that there are no major equipment failures and no extensive additional regulation.

The Cost Review also recommended that BPA market a portion of the FBS equivalent to the planned output of CGS priced in a manner that ensures recovery of the plant's operating costs in the actual sales of the plant's output. Subject to further input, BPA's tentative conclusion is that the problems connected with this piece of the recommendation are not practicably solvable. It would involve selling a portion of the Federal Base System at a higher price equal to CGS's operating costs – a legal difficulty – and reduction of the lowest cost subscription inventory when it appears that we will be oversubscribed. CGS's operating costs are now so close to the market and to BPA's likely subscription power rates that the cost impact of this separation on both the subscription rate and the theoretical CGS rate would be negligible. Equity concerns among parties with subscription rights over who is left with the higher-priced portion of power would likely exacerbate the oversubscription issues (see power markets, revenues and subscription fact sheet). Finally, a robust market test should achieve the bulk of the cost review goal, without creating the substantial problems connected with putting a higher price on this portion of the subscription inventory.⁷

⁷ Bonneville Power Administration. *Issues '98 Fact Sheet #1: Cost Management*. Portland: Bpa.gov, June 1998. PDF.

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Despite these agreements for an ongoing market test, the chaos wrought by the Enron fiasco appears to have superseded all other plans and considerations, and made the continuation of the market test seem unnecessary.

In 2002, CGS’s operator, Energy Northwest, wrote:

Market test

In 1998, a regional cost review made several suggestions for the operation of Columbia Generating Station. Most significantly, the review suggested that the Northwest’s only nuclear power station prove itself on a market basis. As BPA and Energy Northwest eventually constructed the test, the plant’s power would be given a value based upon daily, weighted-average prices at West Coast trading centers. A reasonable amount would be deducted for transmission losses and the cost of transmission.

In every fiscal year since the challenge was made, Columbia Generating Station has proved itself a viable market asset. Since 1999, the total difference between the cost of operating Columbia and the replacement value of its generation is over \$1.526 billion. During the volatile electrical market in 2001 the power worth exceeded cost by a factor of eight due to high market prices and reliability of the station.

Columbia Generating Station		
Fiscal Year	Production Cost*	Power Worth
1999	\$158,000,000	\$174,000,000
2000	\$175,600,000	\$265,650,000
2001	\$199,500,000	\$1,597,246,000
2002	\$196,000,000	\$218,098,000
Total	\$729,100,000	\$2,255,661,000

*Does not include interest and decommissioning costs.

Interest cost ranged from \$132 million to \$110 million during the four-year period. Decommission contributions for the same period range from \$5 million to \$6 million.⁸

This, apparently, was the final mention of the CGS “Market Test.” Bonneville never held a proceeding to implement the Market Test, nor, as far as we have been able to determine,

⁸ Energy Northwest. *Draft Executive Board Report on Nuclear Programs*. 20 Sept. 2002. PDF. Appendix A.

ever mentioned the issue again. Document requests to BPA and Energy Northwest concerning the Market Test have received the response that they were unable to find any relevant materials – although our review has successfully found materials at BPA, Energy Northwest, and the Regional Planning Council.^{9,10}

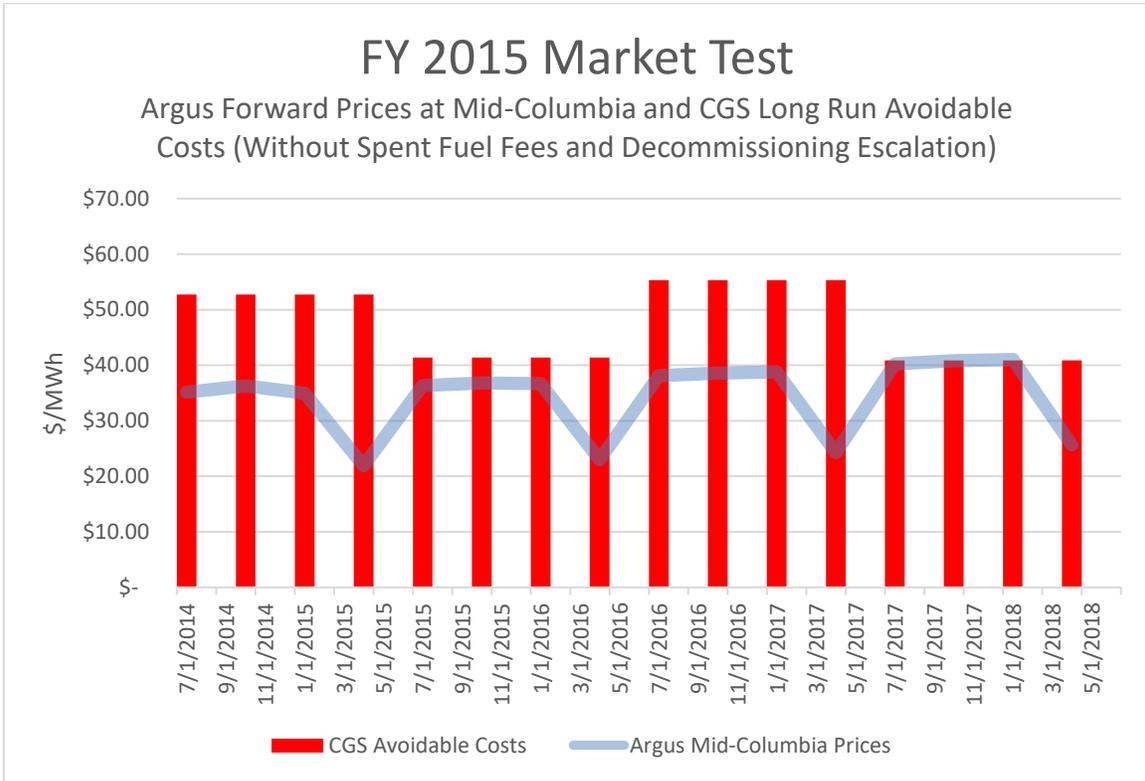


Figure 1: FY 2015 Market Test

In 2013, McCullough Research conducted a market test for CGS, using utility forecasting software and conducting over 30,000 stochastic runs.¹¹ In the chart above, McCullough Research has updated these figures each year based upon actual performance of the CGS and the market.¹²

⁹ Glica, Alex. *Public Records Request 2013-51*. Message to Rose Anderson. 13 Nov. 2013. E-mail.

¹⁰ Munro, Christina. *FOIA #BPA-2013-01739-F*. Letter to Charles Johnson. 5 Nov. 2013.

¹¹ Economic Analysis of the Columbia Generating Station, McCullough Research, December 2013, <https://www.mresearch.com/pdfs/541.pdf>, available in book form from Amazon

¹² Market Cost of the Columbia Generating Station During the FY 2014/2015 Refueling Cycle, McCullough Research, November 2015, https://www.mresearch.com/pdfs/20151116-CGS_costs_exceed_value.pdf and, Columbia Generating Station (CGS) Market Update, McCullough Research, June 2016, https://www.mresearch.com/pdfs/20160621-CGS_Market_Analysis.pdf

CGS has failed the Market Test since 2009 and is likely to continue to do so for the foreseeable future.¹³ Today, CGS fails the Market Test by a significantly larger margin than it has in the past.

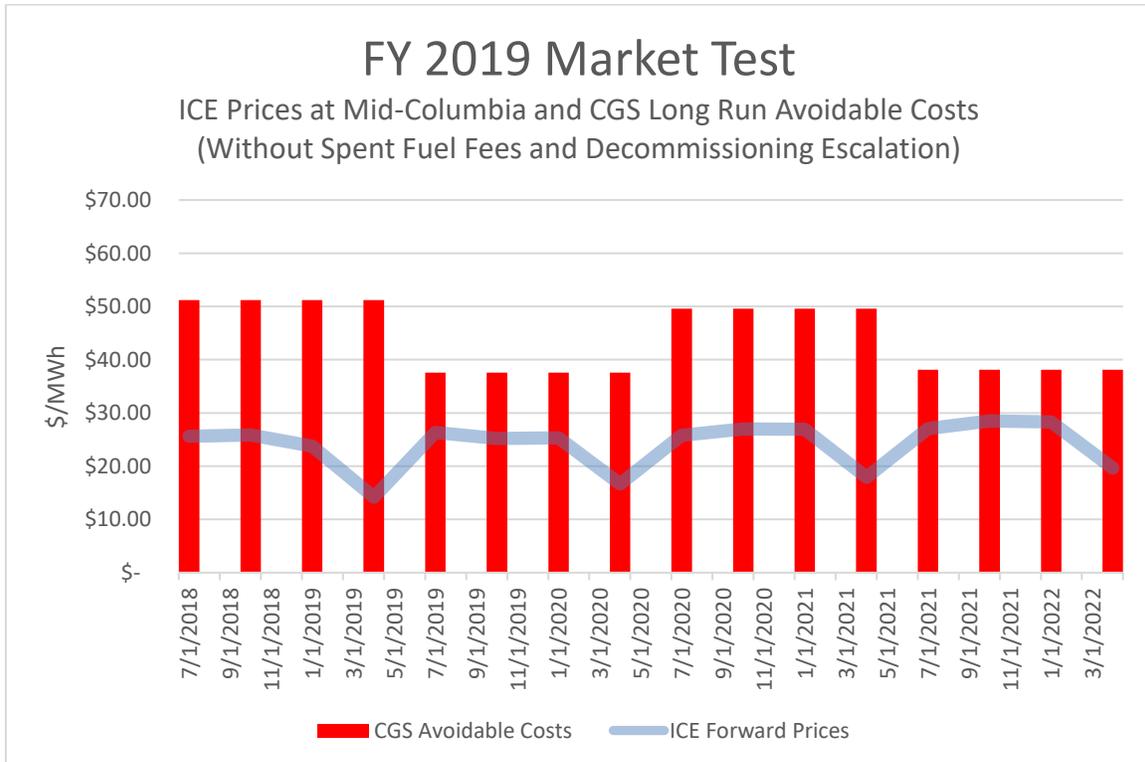


Figure 2: FY 2019 Market Test

One of the largest electric markets in the world is named “Mid-Columbia Hub”; named after the series of dams at the bend of the Columbia River in eastern Washington State that supply a large portion of the region’s electricity. The Mid-Columbia is generally abbreviated to Mid-C. Its prices can be found on the Internet, in many periodicals, and major commodity exchanges such as the Chicago Mercantile Exchange and the International Commodity Exchange.

The graphic below, taken from the U.S. Energy Information Administration’s market price website, shows the nation’s electricity and natural gas trading hubs:

¹³ Economic Analysis of the Columbia Generating Station, McCullough Research, December 2013, <https://www.mresearch.com/pdfs/541.pdf>, available in book form from Amazon

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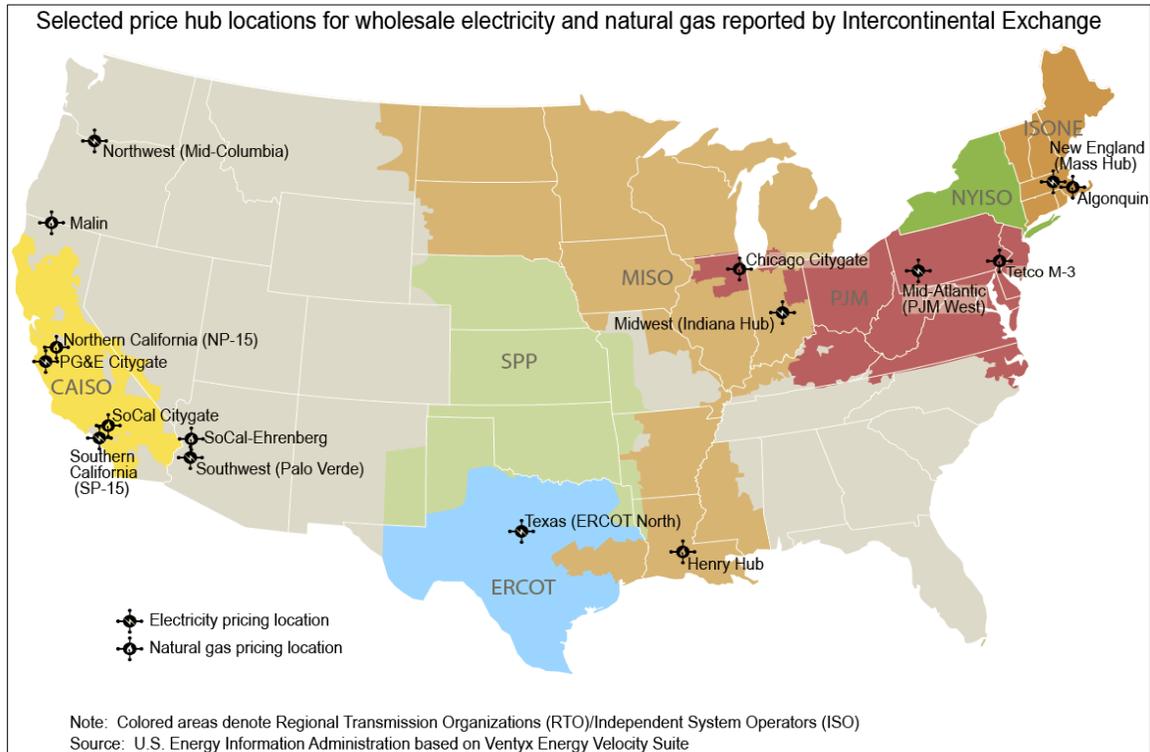


Figure 3: America's Electricity and Natural Gas Hubs¹⁴

In December or 2013, McCullough Research published a three-hundred-page monograph on the plan that established that CGS was not able to meet the market test.¹⁵ This has turned out to be the case ever since.

¹⁴ <http://www.eia.gov/electricity/wholesale/>

¹⁵ Robert McCullough, Rose Anderson, Jil Heimensen, Sean Long Christopher May, Andrew Nisbet, Garrett Oursland, and Marc Vatter. *Economic Analysis of the Columbia Generating Station*, December 2013.

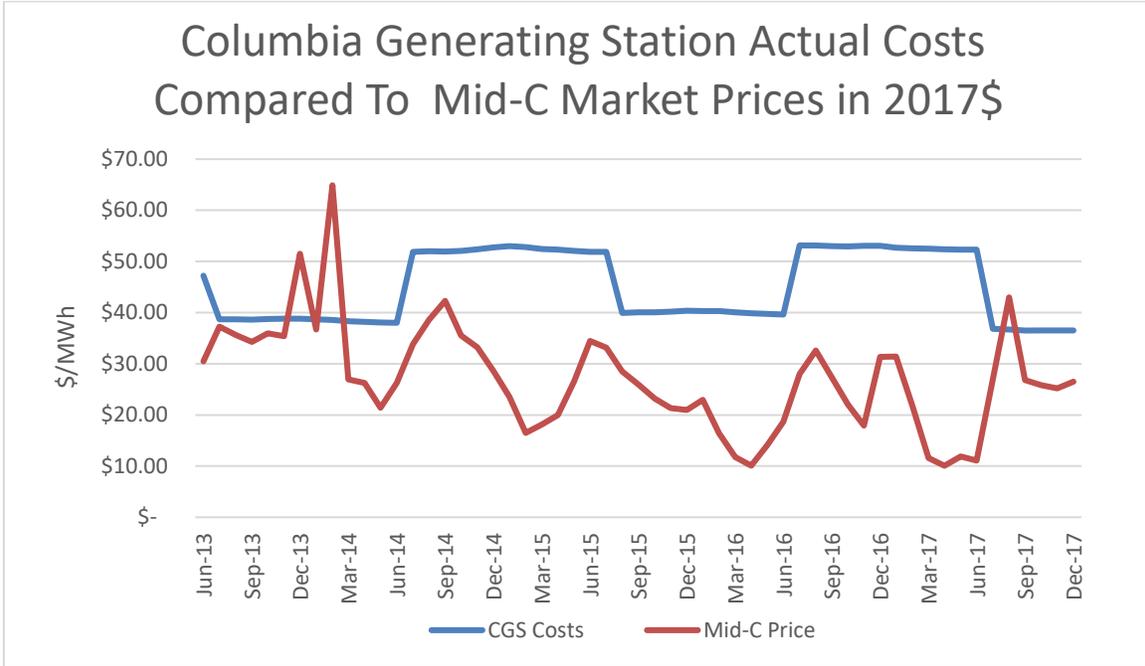


Figure 4: The Price Gap

Over the last four years the Columbia Generating Station nominal cost has been \$826,138,817 more than its output could be sold at market prices. This figure was calculated by taking daily production from CGS and multiplying against the average of peak and off-peak prices sourced from Platts Megawatt Daily. CGS costs were taken from the 2014, 2015, 2016, and 2017 Energy Northwest annual reports.

It is worth noting the marked change in wholesale electricity prices over those past four years, with a fall of over 17% compared to January 4, 2014.¹⁶ This is not unexpected. The western grid is awash with a surplus of clean, renewable sources of energy.

Energy Northwest provides its own forecast of its future cost in their Fiscal Year 2018 Columbia Generating Station Long Range Plan.¹⁷ It predicts future costs ranging from \$51.10/MWh in FY 2019 to \$36.50 per MWh in FY 2022. This makes an easy calculation of the market test. The Market Test specifies comparing forward market costs to the CGS forecasted costs. If BPA were to terminate its contract with CGS today, given that the price of power is only \$14.52 per MWh for BPA to purchase power now for delivery in June 2019, doing so would save \$36.58 per MWh that month, more than a 70% in savings by

¹⁶ This is the difference between the average of peak and off-peak Mid-C prices published by Platts Megawatt Daily for January 4, 2014 and January 4, 2018.

¹⁷ [https://www.energy-northwest.com/whowere/finance/Documents/2016 Budget Documents/Final 2016 CGS Long Range Plan.pdf](https://www.energy-northwest.com/whowere/finance/Documents/2016%20Budget%20Documents/Final%202016%20CGS%20Long%20Range%20Plan.pdf)

simply picking up the phone and purchasing this power from the Chicago Mercantile exchange.¹⁸

The actual savings would be greater than the simple values in the FY 2018 Long Range Plan in a number of ways. First, BPA would avoid four more years of used nuclear fuel to store until a long-term storage facility is found. Second, BPA would avoid the rapidly escalating nuclear decommissioning costs by addressing them today. Most importantly, the forecasts in the previous long-range plans have tended to be over-optimistic by a combination of doubtful assumptions and a lack of consideration of unforeseen events. Since 2007, CGS’s actual cost of power has been 17.9% higher than the projections set out in Energy Northwest’s long-range plan.

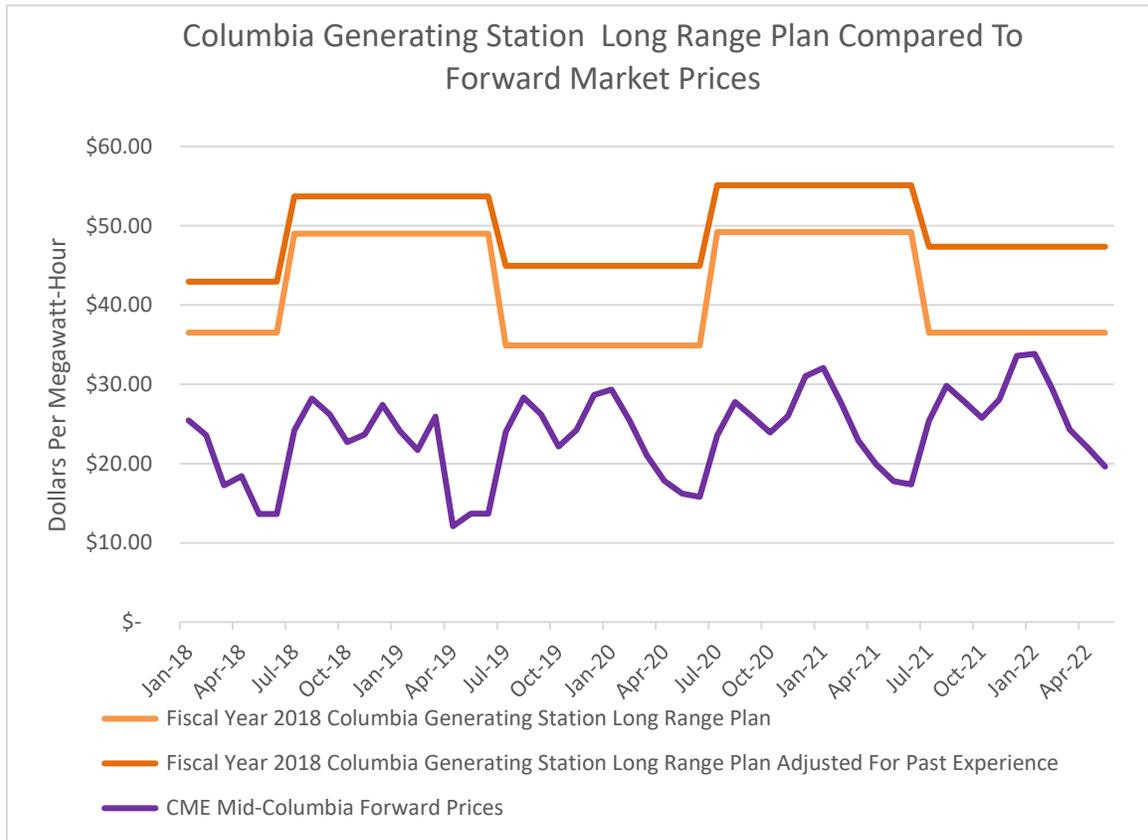


Figure 5: The future gap

The Columbia Generating Station has failed the established market test for the past four years, costing the region \$828.6 million in above-market expenditures, and we project,

¹⁸ <http://www.cmegroup.com/trading/energy/electricity/mid-columbia-day-ahead-peak-calendar-month-5-mw-futures.html> (price accessed January 5, 2018)

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using CME's forward price for Mid-C and Energy Northwest's long-range plan, that it will fail the market test, costing Northwest ratepayers \$513.3 million between FY2018 to FY2022. If we consider Energy Northwest's propensity to underestimate costs in its long-range plans, then the cost to Northwest ratepayers of continuing to operate the CGS versus purchasing Mid-C power on the forward market would be \$692 million.

2. Cost of Carbon-Free Replacement of the CGS

In February of 2017, due to concerns in the region about adding to the carbon footprint of the Pacific Northwest in replacing the CGS, McCullough Research published a report comparing the costs of replacing the CGS with solar and wind resources.¹⁹ Based upon forecast numbers from Lazard's respected "Levelized Cost of Energy" report and Energy Northwest's own forecasts, the report estimated that the net present value benefit of replacing CGS with a solar and wind portfolio would be between \$261.2 and \$530.7 million over the period March 2017 through June 2026.²⁰

It's not even immediately needed. As an important side note, it is important to understand that, contrary to a November 8, 2017 analysis from Energy + Environmental Economics (E3), commissioned by Public Generating Pool (PGP), in collaboration with Benton County PUD and Energy Northwest, it will not be necessary to operate the CGS until 2050 to reduce the region's carbon footprint, even if it were possible to do so.²¹

In 2050, the CGS would be 67 years old, about 16 years older than the oldest nuclear power plants currently operating in the world in Switzerland and New Jersey, both of which are scheduled for retirement in the next few years. It would also be seven years beyond the plant's operating license granted by the Nuclear Regulatory Commission – which, in extending CGS operation until 2043, would already be twenty years beyond its original design life. For a more detailed analysis and a nuclear power amortization table, see Appendix A of our February 15, 2017 study: "Replacing the Columbia Generating Station with Renewable Energy" where a life expectancy model is derived from global nuclear power plant data.²²

Many things have changed since construction began on the CGS on August 1, 1972, and the rapidly decreasing cost of solar and wind energy continued to accelerate in 2017, bringing down our price estimates for replacing CGS with renewable energy from the

¹⁹ https://www.mresearch.com/pdfs/20170215_Replacing_CGS.pdf

²⁰ <https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf>

²¹ https://www.ethree.com/wp-content/uploads/2017/11/E3_NW_LowCarbonStudy_FinalResults_2017-11-08.L.pdf

²² https://www.mresearch.com/pdfs/20170215_Replacing_CGS.pdf

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previous year. Today, using the most recent renewable energy cost estimates from Lazard, and comparing them against Energy Northwest's own projected cost of power, the net present value benefit of replacing CGS with a solar and wind portfolio over a roughly ten-year period between January 2018 through June 2027 is estimated to be \$325.9 million - \$64.8 million more in savings to Northwest ratepayers than the McCullough Research estimate of \$261.2 million from February of last year.

If the historic discrepancy between Energy Northwest projected costs and their actual cost are factored into this analysis, an average error of 17.9%, the net present value benefit of replacing CGS with renewable resources is estimated to be \$575.4 million over the same period – or \$45.4 million more in savings to Northwest ratepayers than was estimated the year before (see Figure 6 on the next page). Year after year, the trend lines increasingly favor renewable energy replacement of CGS as wind and solar become less and less expensive.^{23,24,25}

²³ Lazard. “Levelized Cost of Energy Analysis – Version 11.0.” November 2017. Accessed November 10, 2017. <<https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf>>. This calculation uses the median cost, with federal tax credits, for utility-scale solar and onshore wind, at \$37.50 and \$33/MWh, respectively. See page 4 of the Lazard report.

²⁴ Energy Northwest. “Finance and Long-Range Planning.” Accessed November 15, 2017. <<https://www.en-ergy-northwest.com/whoweare/finance/Pages/default.aspx>>. – should double check this one, too.

²⁵ Robert McCullough, Jacob Gellman, Charles Noble, Xian Ng, and Ted Sand. “Replacing the Columbia Generating Station with Renewable Energy” February 15, 2017, page 3.

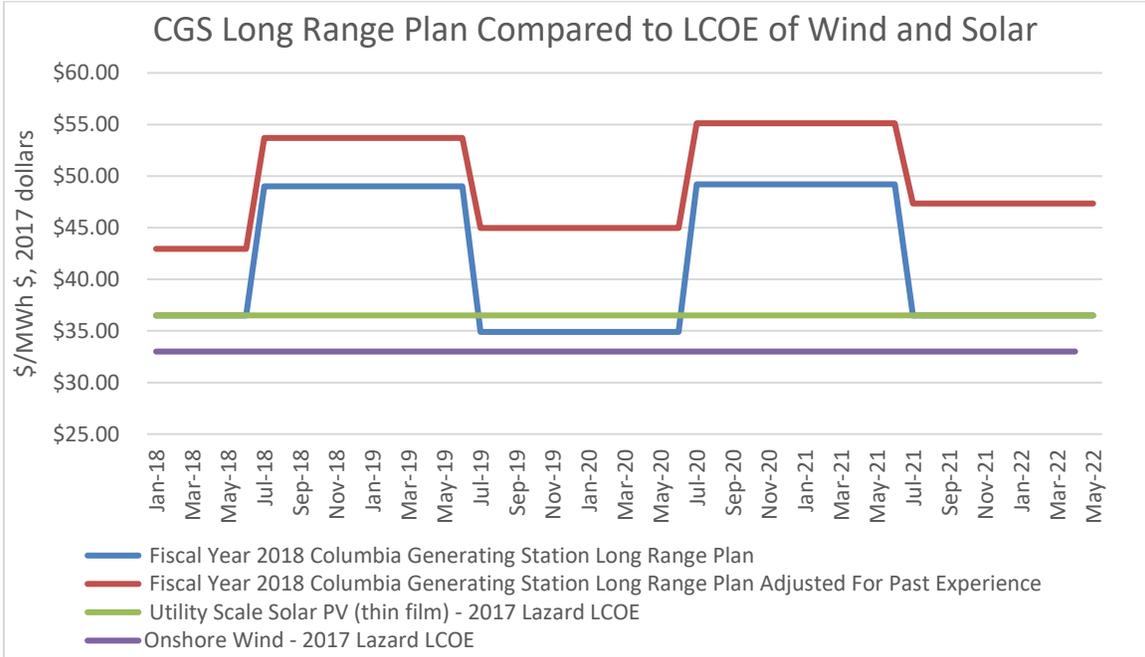


Figure 6: Lazard LCOE compared to CGS long range plan

Thus, whether replacing the CGS with power purchased at market rates or requiring that bids for power be carbon-free, Northwest ratepayers would benefit from replacing the CGS in the coming years. Making the decision to do so sooner rather than later makes it more likely that a smooth transition can be planned, rather than having the decision forced on Bonneville and regional utilities due to equipment failure, as occurred with San Onofre in California and Crystal River in Florida in recent years, or, in the worst case, by a catastrophic accident.

2) Implications of Continued Operation of CGS to Bonneville and Regional Utilities

Twenty years ago, operating WPPSS-2 (now Columbia Generating Station or CGS) required 7% of BPA’s total revenues. This year the value has risen to 13%.²⁶ The problem is the unfortunate nature of the costs of aging nuclear generating units to increase more rapidly than inflation. This is salient for nuclear units, which face extreme heat and radiation related stress to aging equipment and repairs within radioactively contaminated areas which pose special and very expensive challenges.

²⁶ Robert McCullough. “Updating Bonneville’s Strategic Plan” November 21, 2017, page 13.

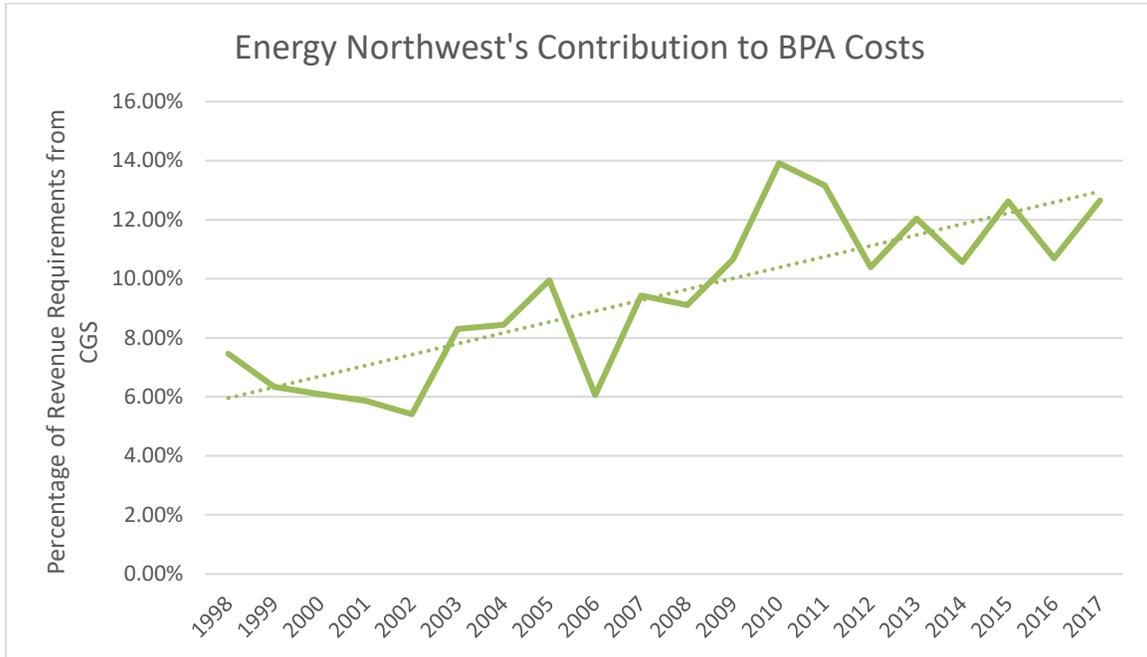


Figure 7: BPA's CGS burden

Although the causes of the increasing pressure on BPA’s finances are more complex than a simple trend, it is useful to see that year by year, the Columbia Generating Station has increasingly dominated BPA’s economics. Earlier this year, Energy Northwest described a nightmare scenario in which BPA rates gradually increased to CGS levels.²⁷ The scenario is extremely alarming since it implies that BPA rates would increasingly diverge from the competitive markets that are open to its primary customers.

To give an idea of this problem’s scale, during Energy Northwest’s Fiscal Year 2017, the Mid-Columbia market price of energy was \$21.55/MWh.^{28,29} The operating cost of the Columbia Generating Station was \$50.40/MWh, forcing BPA to purchase 8,640,000 MWh

²⁷ Columbia IPR 2 and Cost-effective Operation, Brent Ridge and Kent Dittmer, February 15, 2017, slide 10.

²⁸ Platts daily Electricity Report. Jan 1, 2017 – November 13, 2017

²⁹ CME Mid-C Peak Forwards. November-December 2017

from Energy Northwest at \$50.40/MWh to take a \$249 million loss.

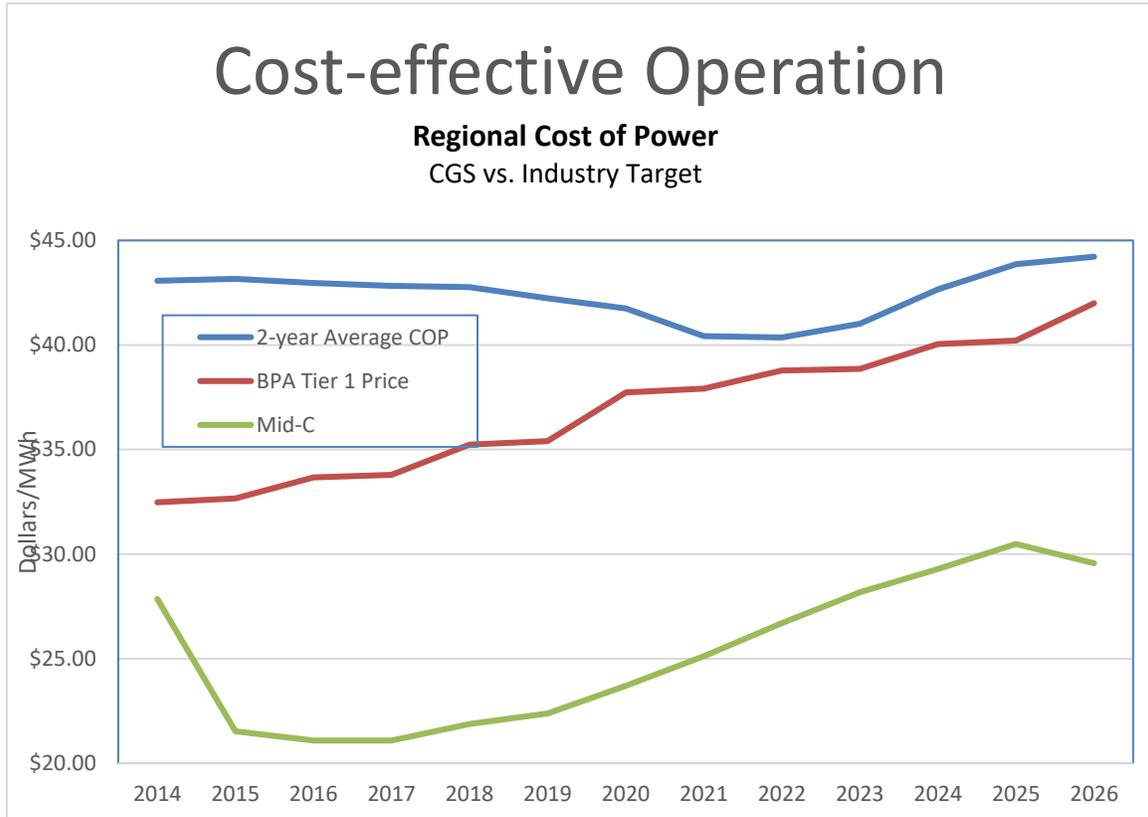


Figure 8: Going in the wrong direction

Figure 8 above displays the forward price of energy at Mid-Columbia from the Chicago Mercantile Exchange.³⁰ As can clearly be seen, even these optimistic forecasts (the blue line) will keep the Columbia Generating Station as a major financial burden for many years to come. In the rest of the industry, nuclear plant costs have been increasing with the age of the unit. Therefore, this chart, using Energy Northwest’s CGS cost projections, as bad as they look compared to the projected competitive cost of power, most likely portrays an unrealistically optimistic vision of the future.

The impact this has on BPA’s financial stability is self-evident. The ongoing borrowing for operations and maintenance costs of the CGS contributes to Bonneville’s continuing challenges regarding high debt ratio and depletion of borrowing authority.³¹

³⁰ <http://www.cmegroup.com/trading/energy/electricity/mid-columbia-day-ahead-peak-calendar-month-5-mw-futures.html>

³¹ https://www.bpa.gov/PublicInvolvement/Cal/doc/Public%20Meeting_BPA%20Strategy_2017.11.17.pdf

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In the last six years, renewables have become increasingly cost-competitive. These gains are expected to continue, allowing renewables to become economically sound on an unsubsidized basis.³² Since FY 2013, the operating costs for CGS have ranged from \$36.50/MWh to \$51.10/MWh even when not including debt-financed O&M costs.³³ CGS is thus moving in the opposite competitive direction as renewable energy.

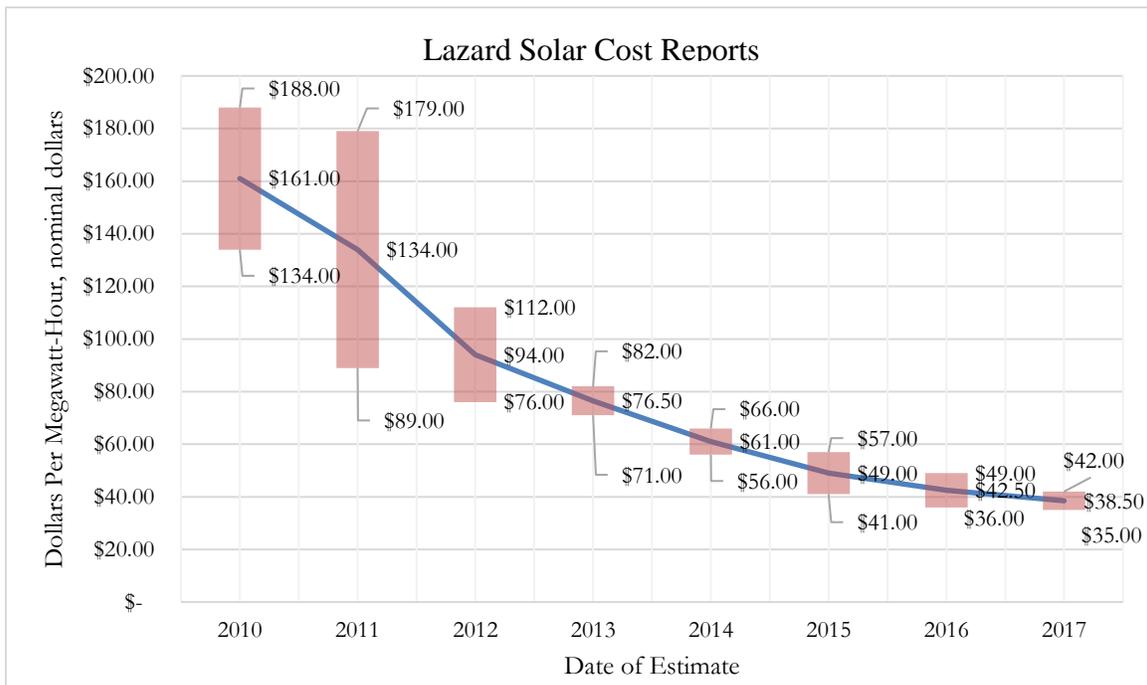


Figure 9: Levelized Cost of Energy for Solar (Lazard Historical Estimates)

³² Lazard. "Levelized Cost of Energy Analysis – Version 11.0." November 2017. Accessed December 20, 2016. <<https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf>>. See page 10.

³³ Energy Northwest. "2017 Annual Report." Accessed December 21, 2017. <[https://www.energy-northwest.com/whoware/finance/Documents/2016 Energy Northwest Annual Report.pdf](https://www.energy-northwest.com/whoware/finance/Documents/2016%20Energy%20Northwest%20Annual%20Report.pdf)>. See page 24.

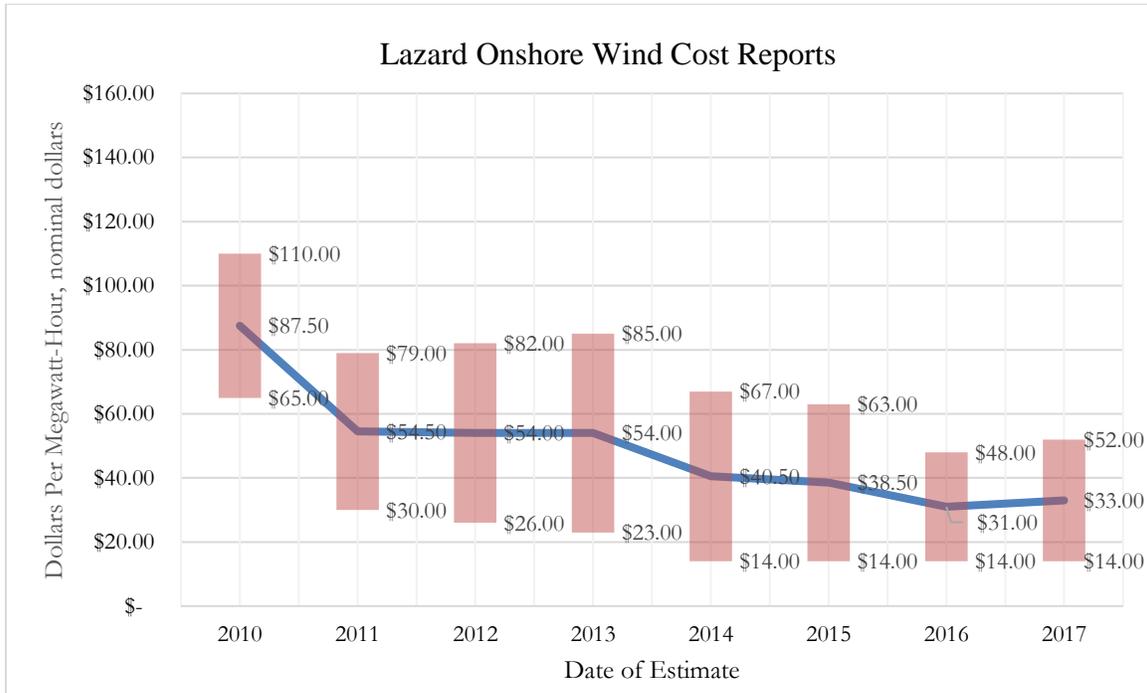


Figure 10: Levelized Cost of Energy for Wind (Lazard Historical Estimates)

These low costs are robustly evident in current RFP bids in North America. The most recent market evidence from the Alberta procurement auction results indicate that Lazard’s estimates may well be too high. In December, the Alberta Electric System Operator received bids for new wind resources at C\$37/MWh equivalent to \$30/MWh in U.S. currency.³⁴ Xcel Energy has now released details on bids submitted in response to its RFP. Many of these bids were for wind and solar installations with a predicted cost of only \$18.10 and \$29.50/MWh.³⁵ That’s America’s energy future. CGS is America’s expensive past.

Conclusion

Ratepayers in the Pacific Northwest need BPA to put the CGS to a market test. The cost of renewable energy from wind and solar is now significantly less expensive than the West Coast’s last nuclear power plant. There are simply better options; Bonneville and its regional customers should pursue them and reap the benefits.

³⁴ <https://www.aeso.ca/market/renewable-electricity-program/rep-round-1-results/>

³⁵ Xcel Energy. 2016 Electric Resource Plan: 2017 all source solicitation 30-day report. December 28, 2017. Accessed January 8, 2018.